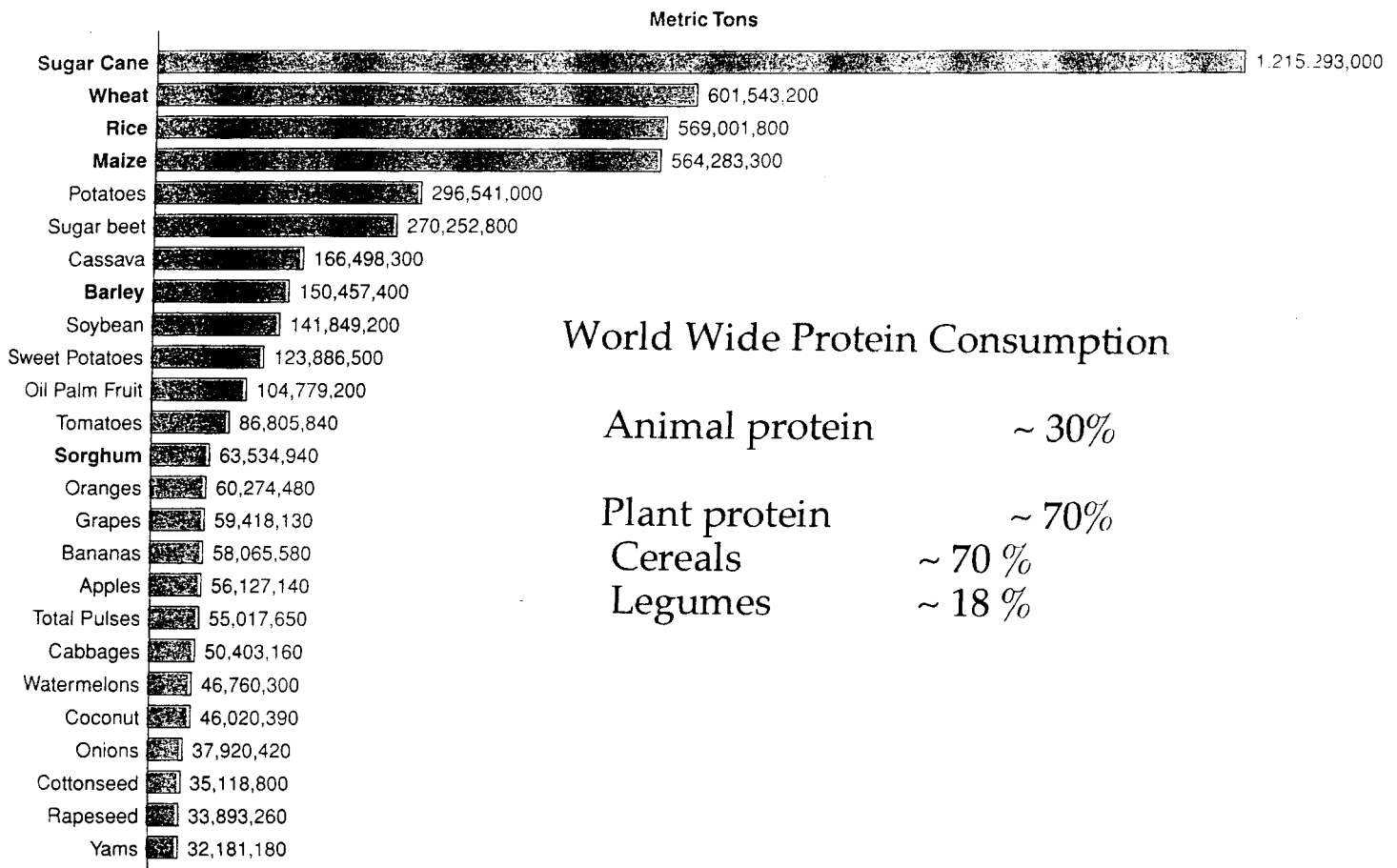


Origin and Evolution of Some Common Crops

I) Annual production of the worlds top 25 crops.



World Wide Protein Consumption

Animal protein ~ 30%

Plant protein ~ 70%

Cereals ~ 70 %

Legumes ~ 18 %

Major Crop Types:

1) Cereals: Wheat, Rice, Corn, Barley & Sorghum

Carbohydrates & Protein (Low in Lysine & Tryptophan)

2) Legumes (Pulse Crops): Beans, peas, soybeans, peanuts

High in carbohydrate, protein (lysine, tryptophan)

Some high in oils (soybeans & peanuts)

3) Roots & Stems: Sugarcane, Potatoes, Sugar Beets, Cassava, Yams

High in Starch or Sugar, Very low in protein, vitamins and minerals

4) Fruits: Citrus, grapes, Coconuts, Grapes, Apples).

High in sugars and vitamins.

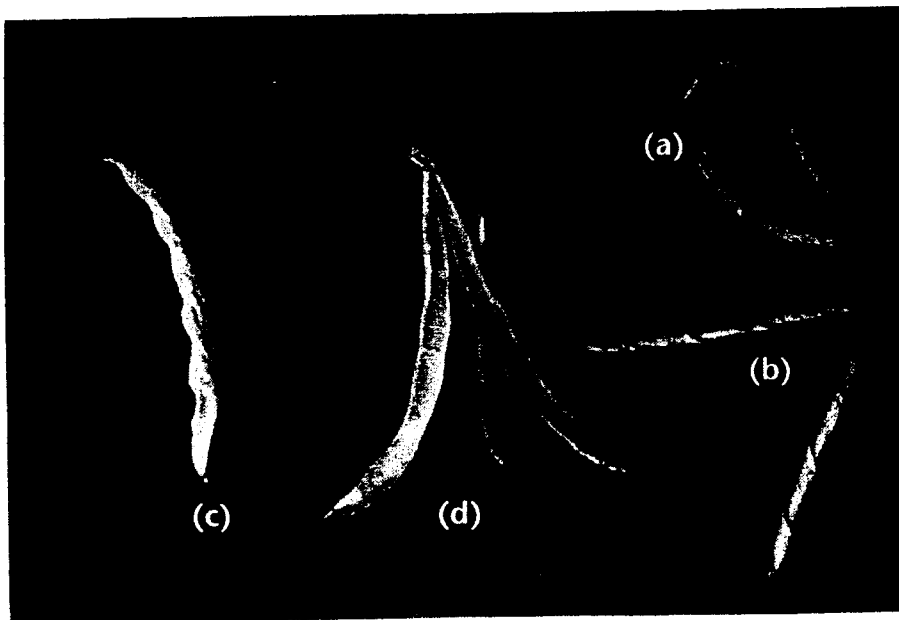
Man has domesticated about 5000 of the thousands of plant species for food, fiber & industrial purposes. Of these, about 15 species supply most of the human diet.

Three important steps in Crop domestication

- 1) Moving plants away from natural habitat to sites chosen by man
- 2) Removal of natural selection pressure by growing in new habitats
- 3) Application of artificial selection by choosing characteristics suitable for agricultural production

Desirable Characteristics used for crop selection

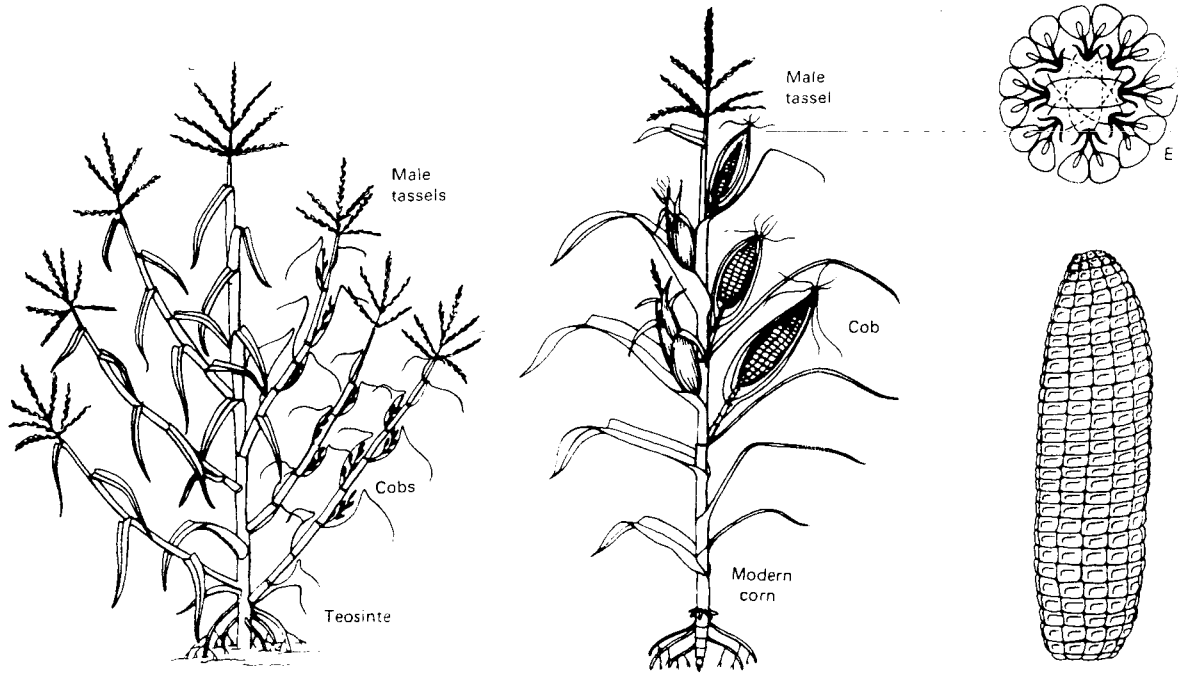
Characteristic	Example
Loss of Dispersal	Corn, Wheat, Peas & Beans
Loss of Dormancy	Wheat, Oats & Rice
Perennial to Annual Growth	Rice, Rye, Cassava
Loss of Fruit Production	Yams, Sweet Potato
Loss of Seed Production	Bananas, Citrus
Increased size of:	
Seed	Bean, Corn, Wheat
Fruit	Squash, Banana, Tomato
Storage Organ	Cassava, Carrot, Beet
Vernalization Requirement	Wheat, Oats
Removal of Toxins	Most Crops
Disease & Pest Resistance	All Crops



Wild Varieties of Beans Scatter Their Seeds But Domesticated Varieties Do Not.
 The dry pods (a) of a wild bean (*Phaseolus vulgaris*) varieties open violently when they are touched, and curl up (b), scattering the seeds on the ground. This characteristic makes harvesting difficult. The dry pods (c) of domesticated varieties must be opened by hand (d) to release the seeds that normally stay inside until harvest time.

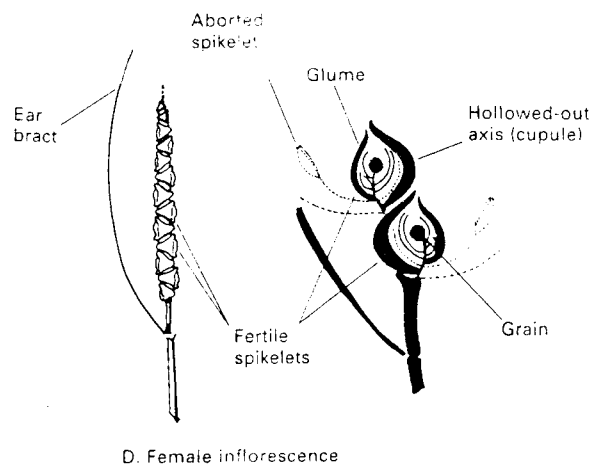
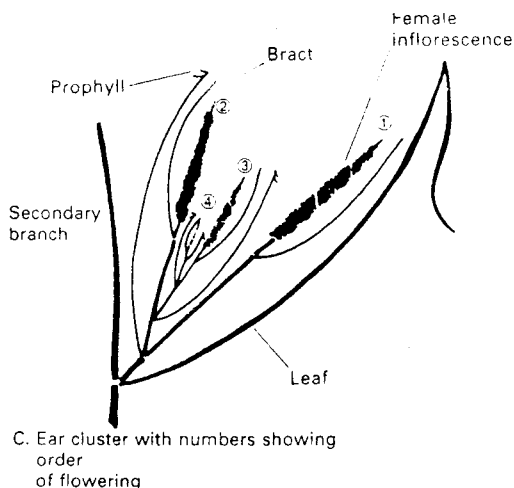
EVOLUTION OF SOME SELECTED CROPS

Corn (*Zea mays*): Thought to have originated in southern Mexico from teosinte (*Zea mays subsp. parviglumis*).



A tassel terminates the primary corn stalk & secondary branches form cobs. Teosinte looks like corn in several ways, but differs in having:

- 1) Secondary branches originating along the primary branch
- 2) Male tassels terminating at ends of secondary branches
- 3) Female inflorescences in clusters along secondary branches
- 4) Immature female inflorescences maturing sequentially
- 5) Ears consisting of 5-12 cup-like seeds sealed by a hard glume

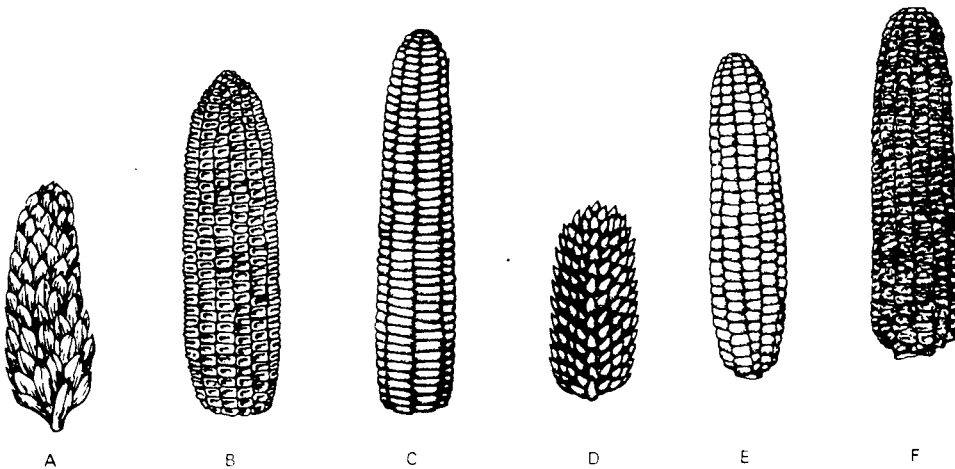


CORN & TEOSINTE DIFFER BY ONLY A FEW GENES

Corn crossed with teosinte produces an intermediate hybrid.

George Beadle found that corn & teosinte differ at 5 simple independent Mendelian genes. These are located on five of the ten chromosomes.

Preserved corn cobs from the Tehuacan Valley of Southern Mexico. The cob on the left is about one inch long. During this time, 5,000 years of selection have produced increasing larger cobs lengthened kernels, and various photoperiod changes suitable for growth in north and south America where corn had spread by the 1500's.



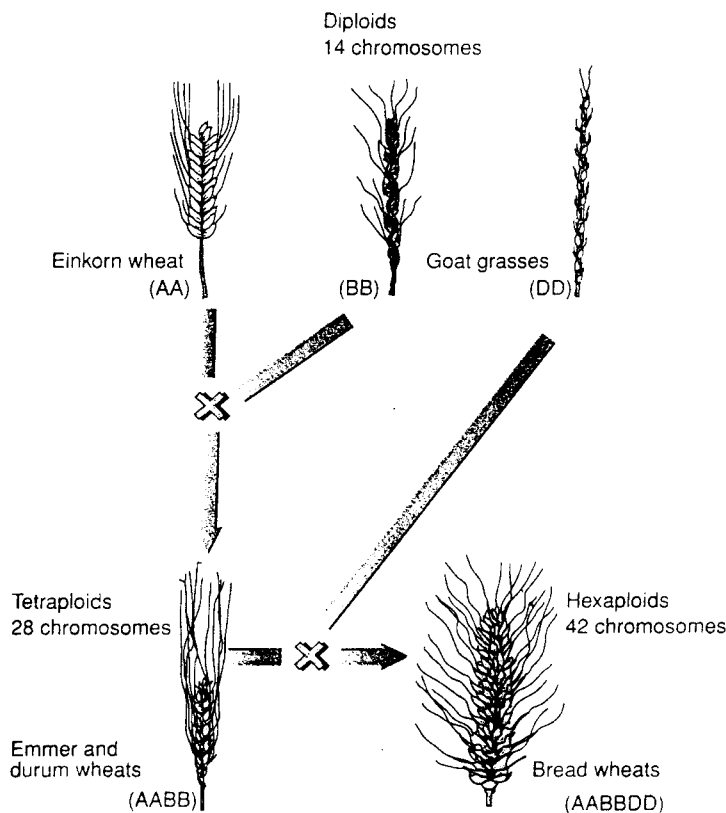
Six main corn varieties have been selected, including **A) Pod corn**, **B) Dent Corn**, **C) Flint Corn**, **D) Pop Corn**, **E) Flour Corn**, & **F) Sweet Corn**.

Maize is now grown all over the world, but half of the world's supply is grown in the USA, where it takes up twice as much land as other crops.

Wheat - (*Triticum aestivum*)- Wheat is an “**accident of nature**”, resulting from crosses with three different cereals. Cultivated by 7000 BC in Near East. Barley was initially more widely grown than primitive wheats, but by the time the Old Testament was written, wheat had become the dominant cereal. In the Book of Genesis, “*Adam & Eve were forced to make their bread from wheat!!!!*”.

Evolution Of Wheat

Wild wheat precursors called **Einkorn Wheat (*Triticum monococcum*)** were diploid ($2n = 14$). Natural mutants selected suppressed shattering. Crosses with a **Goat Grass (*T. speltoides*)** followed by chromosome doubling produced tetraploid ($2n = 28$) **Emmer and Durum wheats (*T. turgidum*)** with chromosomes designated AABB. Later, a cross occurred with a second diploid Goat Grass (*Agelops squarosa*) to form ($2n = 42$) hexaploid **Bread wheat (*T. aestivum*)** with three sets of chromosomes (AABBDD).



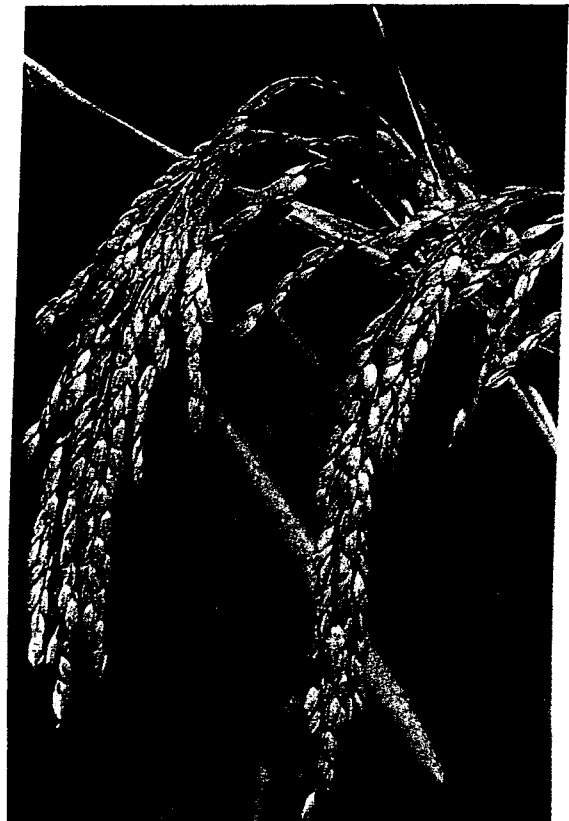
Einkorn wheat is now cultivated in only a few areas of the world. Emmer wheat mutated to produce Durum wheat which separates from the chaff easily and can make raised bread because of a high **Gluten** content. They are however now used primarily for making macaroni, pasta and noodles because the hexaploid wheats contain endosperm very high in Gluten proteins.

There are now over 20,000 wheat cultivars including red, club and white wheats with winter or summer growth requirements. Major diseases are Rusts (*Puccinia spp*) that require efforts of enormous breeding programs to incorporate resistance genes. North America could not grow wheat productively without these breeding programs.

Rice (*Oryza sativa*) - Rice was first domesticated in India, China and possibly Indochina. Terraces have been found in northern India and dated to 10,000 BC, so rice production probably originated at about the same time as cereal cultivation in the Fertile Crescent. Alexander the Great first wrote about rice in 320 BC, and by the time of Christ, rice had spread across the Middle East into Egypt. More people eat rice than any other cereal but more wheat is produced. Rice is considered to be a symbol of fertility, thus the throwing of rice at weddings.

Evolution of Rice

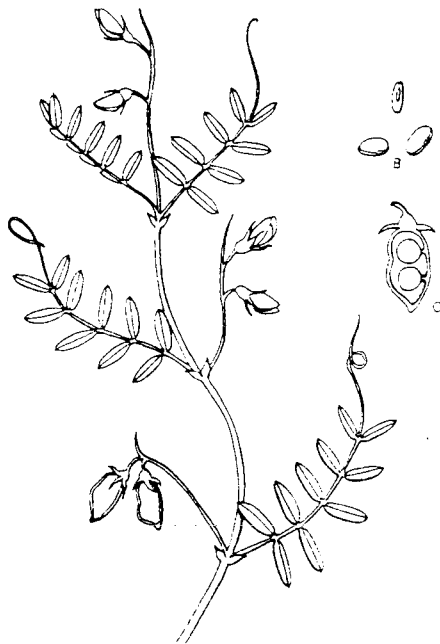
Rice originated from a wild species (*O. rufipogon*) that grows in Asia. The wild species is a perennial that has an enormous amount of diversity. The diversity arises from the ability of the wild plants to cross pollinate and mix genes, whereas cultivated rice is self pollinated. However, cultivated rice and wild rice can interbreed, so it is possible that during domestication, the self pollination trait was selected to maintain domesticated traits. The two species also grow in the same locations and have similar growth habits. They also have similar biochemical markers. As the rice genome becomes sequenced, plant evolutionists will be able to trace the relatedness of these plants more definitively and determine the number of genes responsible for their differences.



Two major subspecies of rice with different cooking properties exist. **Long grain (*japonica*)** rice is dry and cooked grains separate easily from each other. **Short grain (*indica*)** rice becomes sticky and adheres. Upland varieties that do not require irrigation have been bred and very large amounts are grown in Brazil.

Lentils & Peas Originated in the Fertile Crescent

Lentils (*Lens culinaris*) and **Peas** (*Pisum sativum*) both originated from very similar wild relatives from which fertile hybrids can be made. Both of the domesticated plants differ from the wild plants in two major respects. First the domesticated plants do not scatter their seeds and secondly, they germinate uniformly when planted, unlike wild seeds which germinate at various times after planting. Both domesticated plants probably differ in only a few genes from their wild relatives.



Lentils are one of the oldest plants grown by Neolithic man and were prevalent in the same area as chick peas and peas. The crop spread into Egypt by 4200 BC and later into India, Europe, and China. A number of varieties of different colored seeds have been selected. The plant has very high drought resistance. Today lentils are a very important crop in India and are grown in semi-arid regions of the North West USA. Lentil seeds have ~25% protein and ~55% carbohydrate.

Peas were domesticated by at least 8,000 BC. Fossil seeds distinguishable from wild plants by having smooth coats have been found in sites dating to nearly 6,000 BC. The Old Testament indicates that in the court of King Nebucadnezzar, Daniel asked for peas rather than meat in order to avoid violation of dietary laws. Peas grow well in cool weather and formed the primary food for peasants in the Middle Ages. Peas are high in protein (23%) and carbohydrate (>59%), and rank 4th in production behind soybeans, common beans and peanuts. Recent breeding has increased the number of pods per node and selection for synchronous maturation has been instituted to facilitate mechanical harvesting.

Soybeans: (*Glycine max*) have been cultivated since at least 1500 BC and they have been speculated to have been cultivated since ancient times. However, no trace of legumes has been found in Neolithic archeological sites despite rice, hemp and mulberry fossilized remains. In addition since mature seeds must be cooked before consumption, it seems likely that soybeans may not have been an early food source.

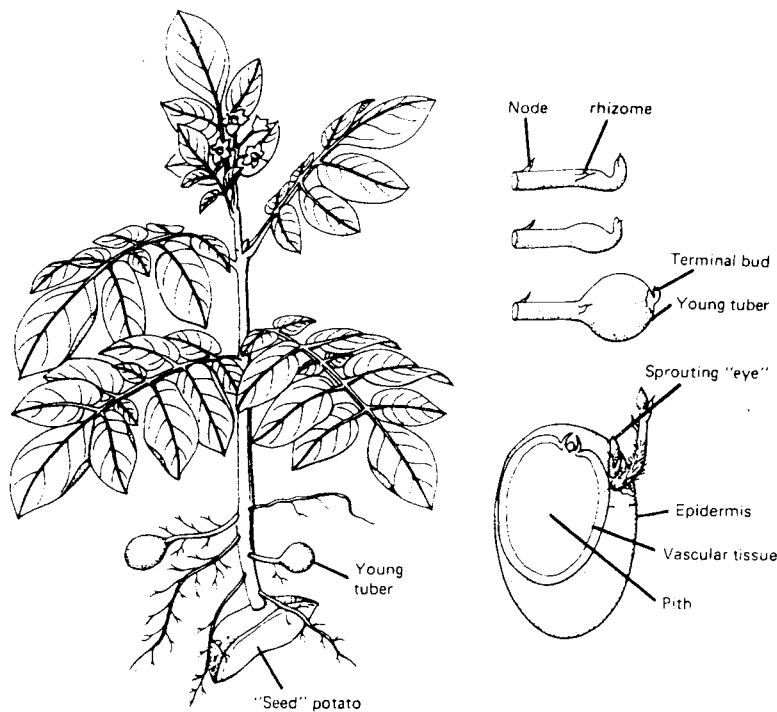
Several wild *Glycine* species exist in nature but the closest relatives *G. ussuriensis* and *G. gracilis* are found in the major soybean centers in Northern Eastern China. Crosses between *G. max* and *G. ussuriensis* and *G. gracilis* are fertile, and all three diploid species have 40 chromosomes. The progeny of crosses have very similar phenotypes to those resulting from crosses of two different varieties of soybean. Therefore, it is likely that *G. max* arose from the wild species via trial and error selection for qualitative and quantitative changes without major chromosome changes.



Mature soybeans are toxic due to proteinase inhibitors, but immature beans and bean sprouts can be consumed. However, cooked beans can be eaten and a very large variety of products are made from this source. Soybeans have a large amount of protein (29%) of any commonly grown legume, the 2nd highest amount of oil (20%), and the lowest amount of carbohydrate (33%). The protein is particularly high in methionine. If cultivars lacking toxic trypsin inhibitors can be removed from mature seed, this will greatly increase the utility of the plant.

Soybeans were not grown commercially in the US before the 1920's, but since then the production has skyrocketed. Brazil has also become a major producer of soybean

Potatoes (*Solanum tuberosum*) belong to the nightshade family. They are the fourth major food source in the world and are now cultivated in more than 150 countries. Potatoes originated in the highlands of South America and archeological evidence indicates that tubers were eaten as early as 9000 BC. Potatoes were taken to Spain by the conquistadors by at least 1580 AD and were later introduced into England. They are high in starch and became a staple food in the early 1800's. In Ireland potatoes provided such a reliable food supply that a population explosion arose and the population grew from 1.5 million to 8.5 million between 1760 and 1840. This set the stage for the **Irish potato famine** caused by **late blight disease** in 1845. At least one million people died of starvation between 1845 & 1850 and another million emigrated to the United States.



Origin and Evolution of Potato

All of the cultivated potatoes belong to eight species present in Western South America. Four of these species are diploid ($n = 12$) and four are polyploid. The progenitor of common potato taken to Europe probably resulted from a cross between two diploids, *S. stenotomum* and a second species whose identity has not been clearly determined. This cross was followed by a chromosome doubling and subsequently additional genes were introduced by out crosses with other species located in the Andean highlands.

Origin and Evolution of Tomato

Tomatoes (*Lycopersicon esculentum*) originated in Mexico. *Lycopersicon* is a relatively small genus within the diverse Solanaceae (Nightshade) family. A subgenomic classification divides the genus into species that can be easily crossed with the commercial tomato (esculentum-complex) and those that cannot (peruvianum complex). The esculentum-complex consists of six species, three of which have green fruit and three of which have colored fruit.

Red fruit

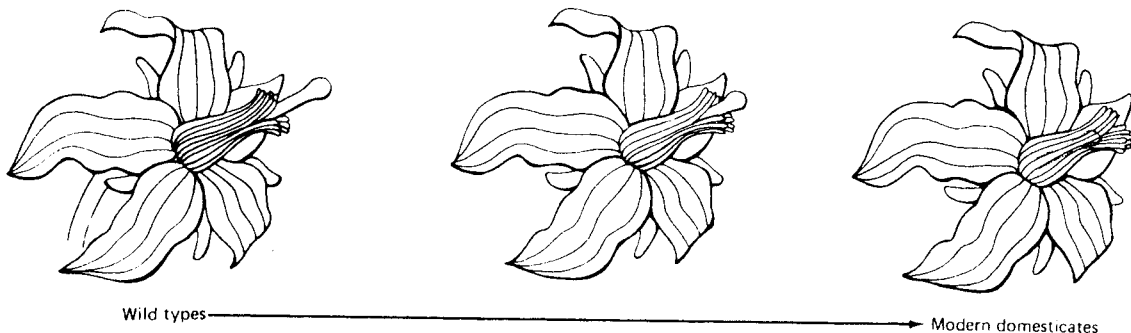
L. esculentum
L. pimpinellifolium
L. cheesmanii

Green fruit

L. parviflorum
L. chmielewskii
L. hirsutum

The cherry tomato (*L. esculentum* var *cerasiforme*) is the only species located outside South America, and this variant is used for food in many parts of Mexico where it grows in the wild as a weed in regions of high rain fall.

Outcrossing was favored in the wild tomato because the **Anthers** are positioned below the **Style**. Humans selected for shorter and shorter styles so that when the wind blows and shakes the plant, the pollen falls directly on the stigma. This selection during domestication resulted in a very high level of self fertilization.



Native Americans selected for an array of fruit shapes, sizes and colors, as well as growth habits. These selections have been amplified considerably during modern plant breeding. Of particular importance for production has been a wide range of disease resistance traits introduced by crosses with the wild esculentum-complex relatives. Sources of resistance to viruses, fungi, bacteria, nematodes and insects as well as cold tolerance have been derived from these sources. High sugar, vitamin C, and solids contents are also being introduced from wild relatives.

Recent Development of a Crop Plant: Sugar Beets

Beet root (*Beta vulgaris*) was cultivated by the Romans for fodder and for cooking and eating. It was derived by selections from a maritime weed, the wild sea-beet (*B. maritima*) that is native to seashores of Europe and western Asia. This plant belongs to the Chenopodiaceae or Goosefoot Family and is biennial. Today beet root is used for soups and leaves for salads.

Wild sea-beet contains about 2% sugar. In 1750's a German Chemist, Andreas Margaraff) noted that some beet root varieties contain up to 6 % sugar and he developed methods for extracting the sugar.

First sugar factory built in Germany in 1801.

Napoleon encouraged studies to increase sugar content of beets when Royal Navy blocked the import of Cane sugar from the Caribbean.

Two Characteristics selected using
progeny evaluation methods:
Increased Sugar Content
Reduced red color caused by Betanin

Varieties now contain up to 20 % sucrose.

One of most striking examples of the speed with which simple selective breeding can direct crop evolution.

Beets were first grown in USA in 1920's. The plant was cultivated extensively during World War II to provide a reliable sugar source.

Sugar beets provide most of the sugar in Europe.

